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July 1966

GCA CORPORATION
GCA TECHNOLOGY DIVISION
Bedford, Massachusetts

SODIUM VAPOR EXPERIMENT

Quarterly Progress Report No. 4

Covering the Period
1 April 1966 - 30 June 1966

Prepared under Contract No. NAS5-3970

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I. INTRODUCTION

The purpose of this contract is to investigate the dynamics of the upper atmosphere through analysis of the motion of sodium vapor trails ejected from sounding rockets. Data are taken photographically from several widely separated sites. Triangulation is used to determine winds from the rate of motion of the trail, and densitometry measurements determine the growth rate and small-scale structure of the trail. Complete descriptions of the experimental and analytical methods are given in reports covering NASA contracts NAS5-215 and NASw-396. Theoretical studies of the dynamics of the upper atmosphere are directed toward formulation of models based on the observations. The first series of rocket firings occurred during November 1964 from Wallops Island and simultaneously from a ship at selected distances from Wallops Island. The objective of the series was to investigate the variation of the vertical wind structure at two places separated by different distances.

The results of the first series were seriously limited by vaporizer malfunction, but one set of trails separated by 180 km showed the winds to differ significantly above 120 km. Previous analysis of several up and down trails separated by a distance of about 50 km have shown no wind variations over that distance. Continuation of the study of horizontal variation of the vertical wind profile was an objective of a series of flights from Wallops Island during June 1965. Two vapor trails were ejected from rockets fired nearly simultaneously on different azimuths during the evening twilight of 22 June and the morning of 23 June. A fifth rocket ejected a trail of TMA at 2300 EST on 22 June to allow observations of the time variations of the winds.

The spatial separation of the simultaneous trails in June was not large and the differences in the wind profiles were small. The evening trails were separated by only 25 km, and the wind speed around 100 km was only about 30 m/sec. The trail separation and wind speed of the morning trails were greater than those of the evening trails. The TMA trail, because of poor rocket performance, did not reach the predicted altitude and faded very quickly, causing some loss of data in the 100 to 125 km region and reduced the accuracy of the data below that height. Thus, the information on spatial variations is limited. Much more information was obtained from the time-spaced trails. The low wind speeds during evening twilight had increased by a factor of 2 to 3 by 2300 EST (about 3 hours later) and the familiar spiral pattern had begun to form. The clockwise spiral was even more apparent over much of the height region by morning twilight and the whole pattern had been continually rotated through the night, as has been previously observed in other time sequences in January and July 1964. The observations should be more closely spaced in order that the exact nature of the changes may be determined. Such closely spaced observations were the purpose of the series of firings at Wallops Island in January 1966.

During the night of 17-18 January 1966, five vapor trail payloads were successfully launched from Wallops Island. This series showed that observations spaced an hour or two apart provide much information concerning the manner in which the winds vary. Some of the initial observations were discussed in the last Quarterly Report covering the period 1 January 1966 - 31 March 1966. It was shown that the large scale spiral pattern collapsed into an irregular low speed pattern in about 6 hours and that the entire pattern moved slowly downward.

This report contains some further discussion of these observations and also some remarks concerning the apparent "turbulent" structure around 100 km.

During this period the payloads for a series of firings in July were constructed. Some of the plans for this series are also discussed in this report.

II. WINDS

At the present time the dynamics of the atmosphere above 80 km is usually described in terms of either of two theories both of which were initially proposed as explanations of the observations of apparent motion of ionized trails created by meteors and detected with a relatively low frequency radar. Winds in the region 80 to 105 km were obtained from meteor trails by Greenhow and Newfeld(1) at Jodrell Bank in England and by Elford and Roper(2) in Australia. Both of these groups of observers separated the observed winds into a prevailing component cyclic components with periods of 24, 12, and 8 km and a large irregular component The irregular component was explained as turbulence derived from a mean tidal flow. Roper and Elford(3) have recently reaffirmed their position that the observed irregular structure in upper winds is due to turbulence.

The other current theory is that proposed by Hines(4) which attributes the irregular winds reported in the meteor data to the well publicized "Gravity-Waves".

The original meteor data was averaged over both height and time intervals and uncertainties in space and short time variations prevented the verification of either of the proposed theories with the meteor data alone. A major objective of the sequential vapor trail measurements is comparison of observed time variations with those predicted by the current theories. The sequential firings during January 1966 demonstrated that observations separated by one to two hours provide a good sampling of the large scale wind variations and also allowed the determination of an apparent downward motion of the entire pattern.

The variations in the large scale wind pattern is shown clearly in Figure 1. Hodographs of the winds from the first four firings show that a large spiral pattern collapsed to a small irregular pattern during the six hour interval. It appears that the spiral shape of the hodograph first became elliptical and then reduced to the small irregular pattern. The reverse of process was reported by Rosenberg[5] from Eglin, Florida, in December 1962 and is shown in Figure 2. Both the spiral and elliptical patterns are often observed at Wallops Island.

The apparent downward motion of the pattern is shown in Figure 3. The open circle points were determined from persistent small scale structure which appeared on the direction of transport plots: The open circles with dots and the solid circles were obtained from the heights of the maximum wind speed of E-W and N-S components during the observing period. It can be seen from Figure 3 that the rate of downward motion of the large scale pattern is the same as that for the smaller structure and that this velocity decreases with decreasing altitude. It is not obvious from these measurements whether the downward motion is a true mass motion or the phase velocity of a slowly propagating wave. One of the objectives of the July series of vapor trails is to determine if this downward rate continues throughout the night as would be expected of a travelling wave or if the rate decreases toward dawn as would be expected of a mass motion due to cooling during the night.

Recently, a team of French investigators under the direction of A. Spizzichino presented preliminary results[6] on their observations of ionized meteor trails with a newly developed phase measuring radar technique.

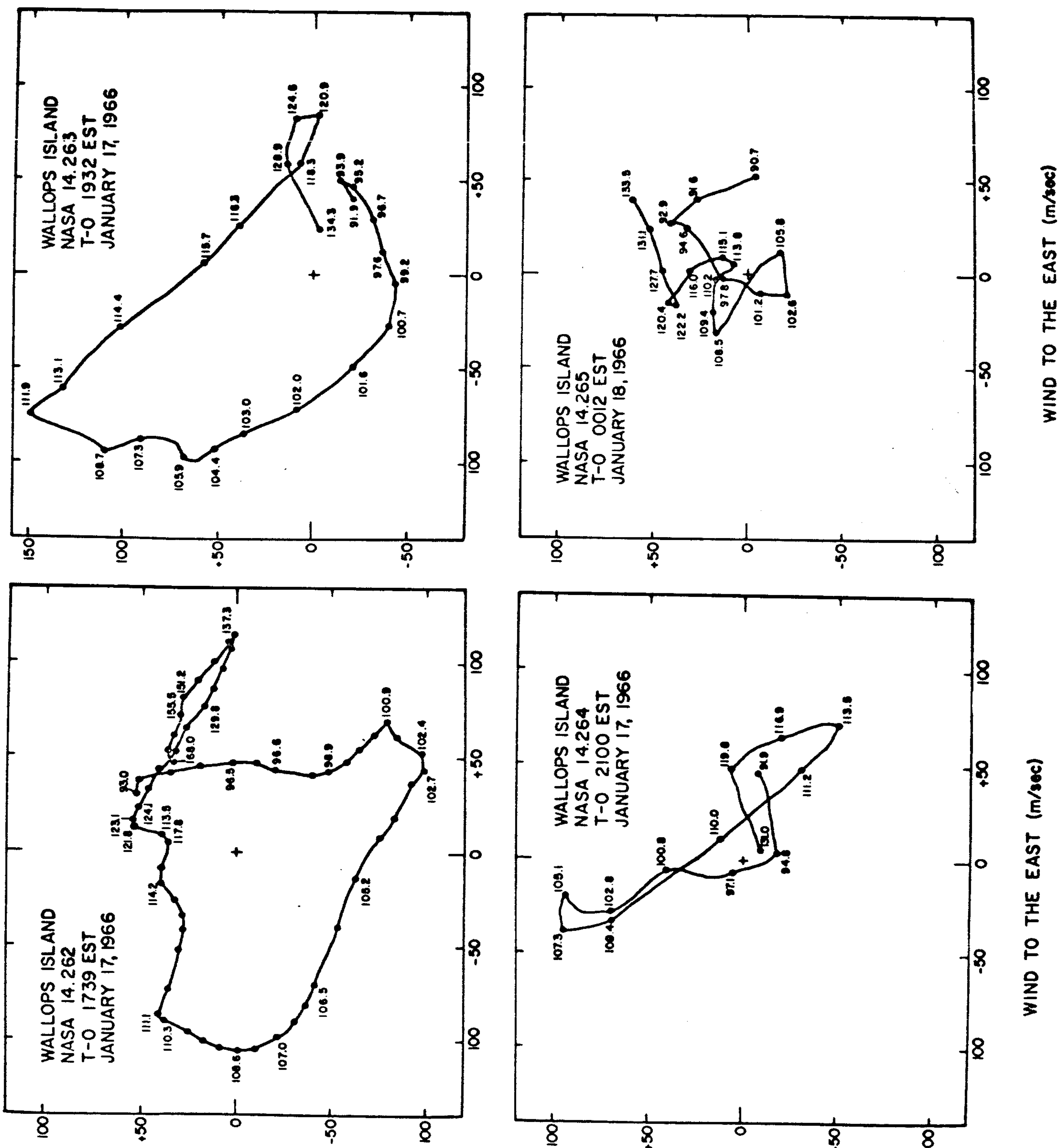

WALLOPS ISLAND
NASA 14.262
T-O 1739 EST
JANUARY 17, 1966
WALLOPS ISLAND
NASA 14.263
T-O 1932 EST
JANUARY 17, 1966
WALLOPS ISLAND
NASA 14.264
T-O 2100 EST
JANUARY 17, 1966
WALLOPS ISLAND
NASA 14.265
T-O 0012 EST
JANUARY 18, 1966
WIND TO THE NORTH (m/sec)
WIND TO THE EAST (m/sec)

Figure 1

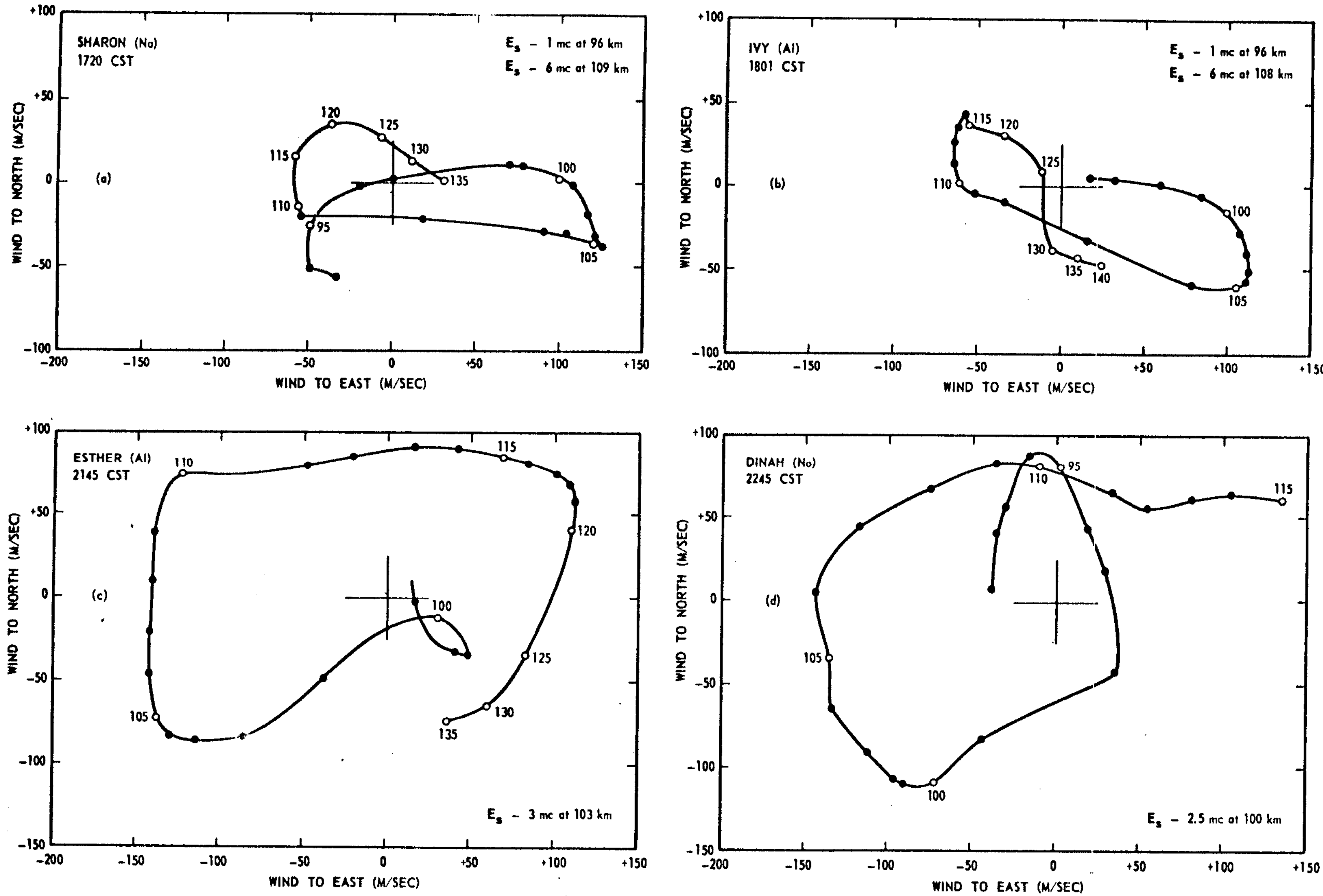

SHARON (Na)
1720 CST
E_s - 1 mc at 96 km
E_s - 6 mc at 109 km
(a)
IVY (Al)
1801 CST
E_s - 1 mc at 96 km
E_s - 6 mc at 108 km
(b)
ESTHER (Al)
2145 CST
E_s - 3 mc at 103 km
(c)
DINAH (Na)
2245 CST
E_s - 2.5 mc at 100 km
(d)
WIND TO NORTH (M/SEC)
WIND TO EAST (M/SEC)

Figure 2

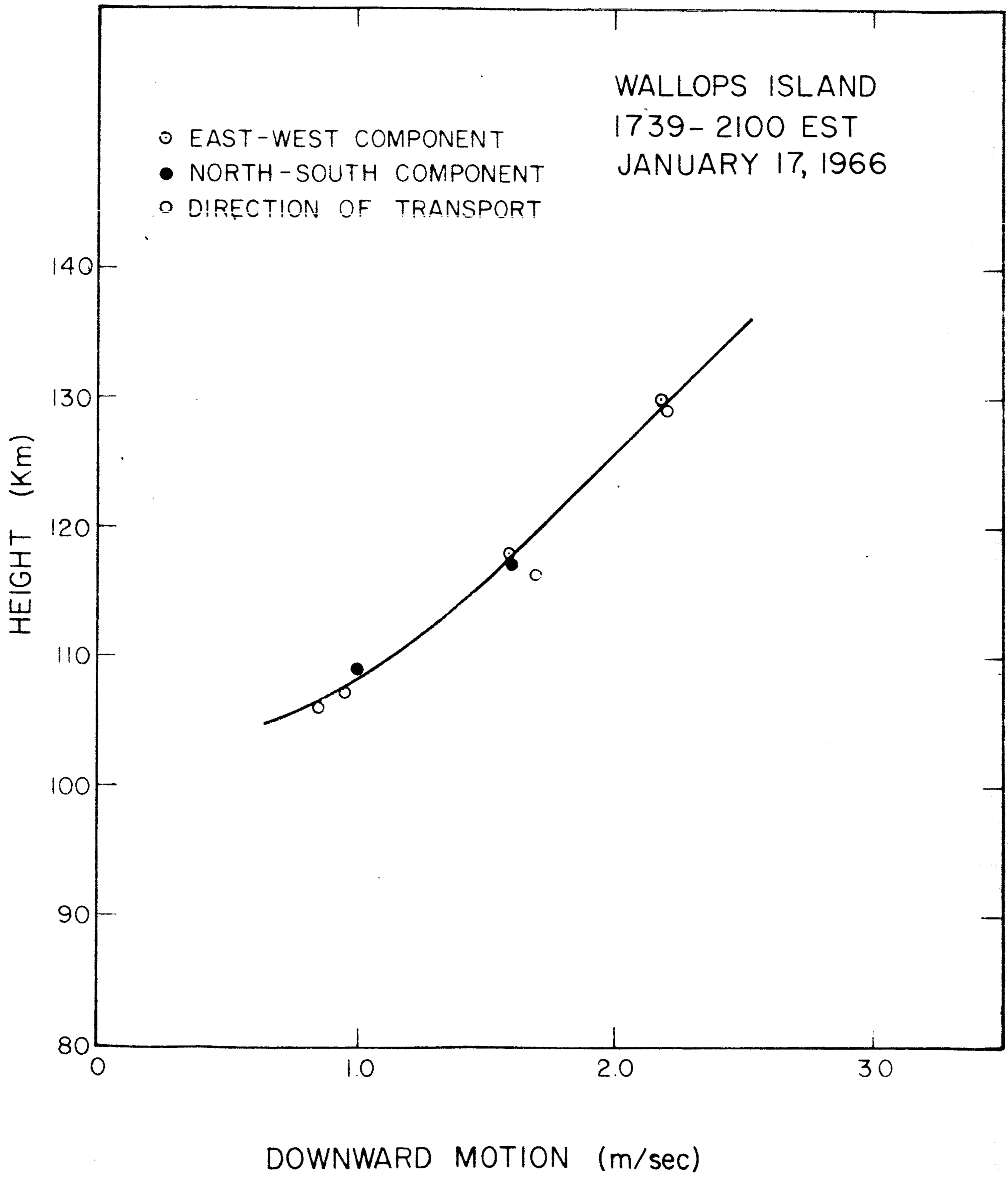

WALLOPS ISLAND
1739- 2100 EST
JANUARY 17, 1966
EAST-WEST COMPONENT
NORTH-SOUTH COMPONENT
DIRECTION OF TRANSPORT
140
130
120
110
100
90
80
HEIGHT (Km)
0
1.0
2.0
3.0
DOWNWARD MOTION (m/sec)

Figure 3

Initial reports on the new method indicate that it has much greater sensitivity and height discrimination than the original radar method. The present data are from very few observations but a similar downward motion of the entire wind profile is indicated over a 24-hour period. This suggests that the motion is the phase velocity of a slowly moving wave system. The new meteor data also indicate that there is a sudden increase in the East-West component of the wind around 100 km just after sunrise at that altitude. The July series is expected to allow observations of these effects. The proposed firing schedule is as follows:

Firing Time	Vapor Trail
2000 EST	Na-Li (Twilight)
0000 EST	TMA
0200 EST	TMA
0330 EST	TMA
0400 EST	Na-Li (Twilight)

III. TURBULENCE

Observations and conclusions concerning the existence of turbulence in the atmosphere, based on the visual appearance of vapor trails in the region around 100 km, have been discussed in previous reports on this contract. Briefly, it has been reported that the irregular structure on the vapor trails does not have the detailed characteristics expected of hydrodynamic turbulence. The observed rapid growth rate without change of shape of the trail and small structure, the linear time dependence of the growth, and the independence of wind shear are characteristics of the trail structure. These characteristics are not described by current turbulence theory. Also it has been suggested that the observed rate of growth of vapor trails, 3 to 5 m/sec, around 100 km is too rapid to be consistent with other observed phenomenon such as sporadic E, if such growth were due to turbulence of the ambient atmosphere. Thus, it was concluded that the irregular structure observed on vapor trails around 100 km may be due primarily to effects of the vapor ejection method and rocket passage and that these effects are so great that they mask the smaller effects of pre-existing turbulence, if such really exists.

Recently, Professor J. Blamont[7], presented a revised discussion of his position that the vapor trails irregularities are due to atmospheric turbulence. The revised hypothesis is based primarily on early, detailed photographs of one vapor trail. Regular variations in brightness of the trail with height were clearly resolved on the photograph. These variations were reportedly caused by the combination of ejection method and character of the rocket flight. At certain altitudes these small irregularities disappeared sooner than at other altitudes and this effect was interpreted as indicating the presence of pre-existing turbulence in that region. The conclusions were based on observations made within 10 seconds of release time. Since the effect of the passage of a supersonic rocket and of the ejection of the vapor has not been completely evaluated, it seems pertinent to inquire if such early time observations could be free of these effects and could be expected to contain much information concerning the ambient atmosphere.

Early time photographs of trails have often been obtained from Wallops Island trails. The photography is difficult so that often early details of structure and growth are uncertain. However, sometimes the growth of the trail is clearly recorded. Such a sequence is shown in Figure 4. The small irregularities in the trail around 100 km and the repeated variations in brightness above and below this height are due to the action of the rocket and vapor ejection system. The appearance of such small structure generally varies greatly with altitude due to the rapidly decreasing diffusivity and also by the wind pattern and angle of view. The irregularities on the trail in Figure 4 continued to be smoothed by diffusion until a later time when the development of the usual "globular" structure obscurred all other effects from 100 to 110 km and the "stringy" structure developed below this height. None of the effects reported by Blamont are observable in this region and the delayed appearance of the globular structure is not characteristic of turbulence. However, this property is observed in Tollmien-Schlichting waves which appear in boundary layers and transition regions of the flow around an ogive in a wind tunnel[8].

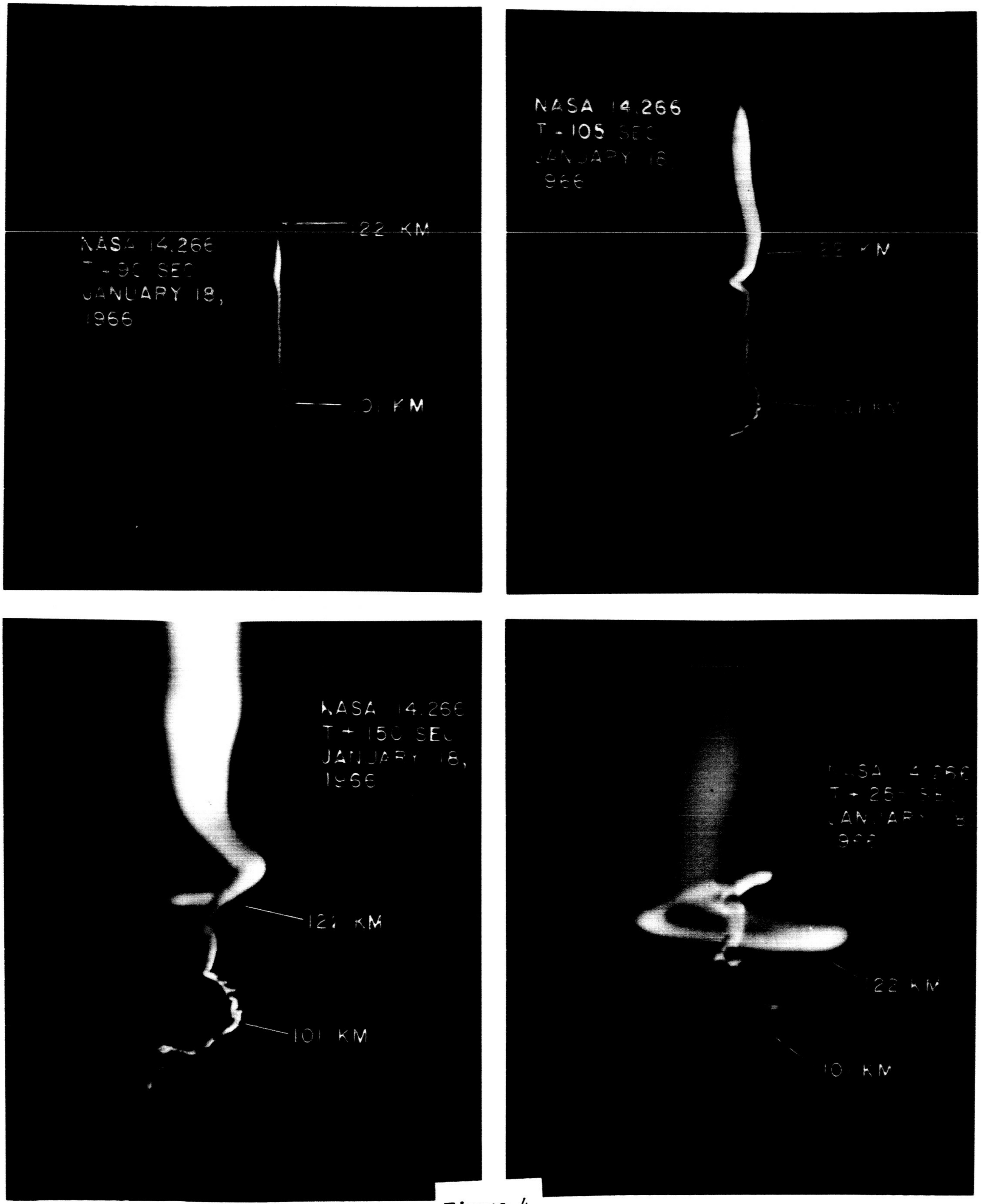
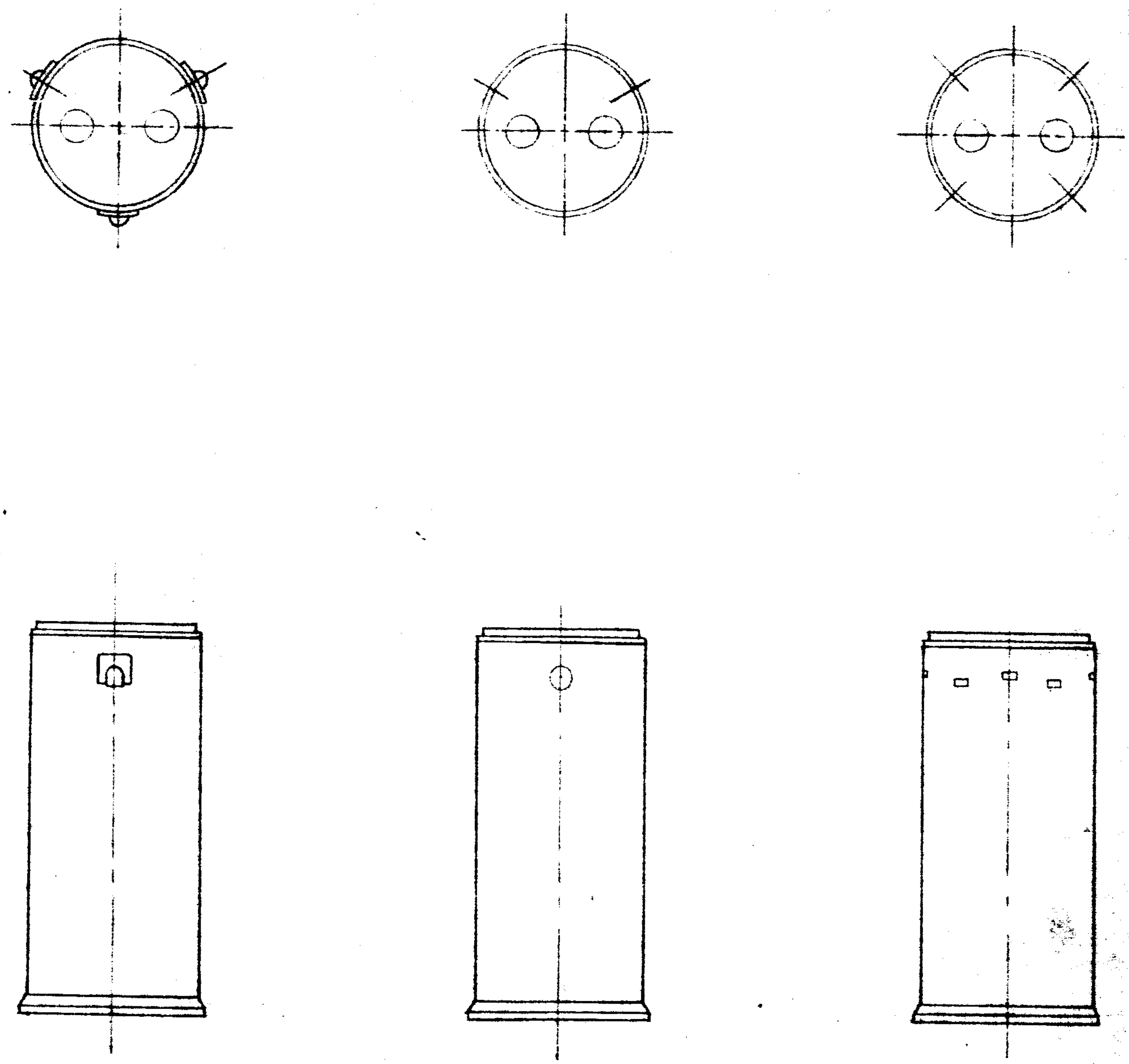


Figure 4

A study of the effects of the shock wave of the rocket and the method of release of the vapor is planned. Some slight modifications of the vapor ejection method are planned for the next series of firings at Wallops Island in July. These changes are shown in Figure 5. The standard canister with three ports, 120° apart, is shown in the center. These ports with deflectors to direct the vapor backward along the rocket body and reduce the effects of forward rocket motion are shown on the left. A canister with 8 ports, 45° apart to reduce the apparent effects of rocket spin, is shown on the right. These canisters will be fired during the morning and evening twilights during the July series of vapor trails. K-24 cameras with 20-inch focal lenses will be observing the early trail growth from Dover AFB, Andrews AFB, Dam Neck Naval Training Station. A 36-inch lens will be used at Camp A. P. Hill. It is expected that the results of these simple modifications may suggest which of several more complicated changes would be useful.



STANDARD CANISTER
3 PORTS 120° APART
WITH DEFLECTORS

STANDARD CANISTER
3 PORTS 120° APART

STANDARD CANISTER
8 PORTS 2 ROWS
OF 4 EACH
45° APART

Figure 5

IV. FUTURE PLANS

A series of five vapor trails are scheduled for the night of 12-13 July 1966. Payloads will be taken to Wallops Island and prepared for flight. Camera sites will be established at Dover AFB, Andrews AFB, Camp A. P. Hill, and Dam Neck Naval Station.

After the rocket firings, data will be processed and analyzed in terms of the stated scientific objectives. It is expected that the analysis will continue throughout the next reporting period at which time conclusions and recommendations will be presented.

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